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Report for the Coronado N.F./Regional Analysis Team

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by

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Summary

Insect activity for the Coronado N.F. was summarized from USDA Forest Service Region 3 Insect and Disease Annual Conditions Reports for 1940 through 2005. Data is missing for the 1960s. Over the period of record, pine bark beetles have affected the greatest area, and insect damage has been most severe in the spruce-fir type. Bark beetle activity in the pine type has been at endemic levels except during the 1950s and the 2000s droughts. Throughout the Coronado N.F., approximately 36,000 and 16,000 ac were damaged by pine bark beetles during the 1950s and 2000s, respectively. Bark beetle activity in the mixed-conifer appears to be episodic as well, with damage in the 1950s and late 1990s through the early 2000s. More acreage was damaged in the early episode than in recent years, and it is not clear if the bark beetle activity in the mixed-conifer is associated with drought or other factors. Insect activity in the spruce-fir type has been unusual in recent years in the multitude of species incurring outbreaks and in the severity of damage. The recent insect activity in the spruce-fir vegetation types is associated with warm temperature patterns. Recent damage to aspen is unprecedented in the record. Compared to insect activity associated with the 1950s drought period, contemporary insect activity has occurred on a comparable acreage, been similar in severity in the pine and mixed-conifer vegetation types, been much more severe in the spruce-fir, and has involved more species of insects, some with potentially more aggressive population dynamics. These differences may be due to the condition of the contemporary forest, warming climate, the temporal coincidence of drought with warmer temperatures, and the introduction of an exotic.

Aerial Detection Surveys in the Coronado N.F.

Insect activity for the Coronado N.F. was summarized for 1940 through 2005 from USDA Forest Service Region 3 Insect and Disease Annual Conditions Reports, including a 1952 report specific to the Pinaleño Mountains (Bennett 1953). Condition reports are missing for 1959-1963, 1965-1970, and 1981.

Insect activity reported in the Conditions Reports is based mostly on aerial detection surveys that are flown in July and August by Forest Health Protection (formerly Forest Pest Management). Staff flying over the forest in fixed-wing aircraft identify and map insect damage onto paper maps. The conditions reports provide excellent information on the acreage affected by insects in each vegetation type. Information on specific locations and severity of impact are less well recorded. Older records are often narrative in nature, and frequently do not quantify the area damaged. In recent reports, affected acreage is usually cross-tabulated by insect agent and by National Forest and Indian Reservation, and

described in the text by insect agent. Narrative references to more specific locations and damage severity are not consistent.

There are some known issues with such survey data when used for evaluating the period of record. Historically, the surveys were designed to report impact to timber resources, and later included recreation resource impacts. This has changed over time, and Forest Health Protection now tries to report all significant damage. In recent times, there has been so much insect activity over such immense areas (Region-wide) that ground truth surveys have not been possible for much of this damage. Also, across the West survey efforts tended to be less extensive during wars and economic depressions, and occasionally in individual Regions at other times, when there were staffing problems.

Identification of damage from various insects from the air is challenging, and it can be difficult to distinguish damage from different insects that cause similar types of damage on the same tree species; *e.g.* roundheaded pine beetle and western pine beetle in ponderosa pine. Some ground-truth site visits are done in order to confirm the damage agent, but not consistently. Ground-truth site visits are usually done for unusual damage, such as the defoliation in the spruce-fir type seen in the late 1990s in the Pinaleño Mountains and White Mountains of Arizona.

The aerial surveys are timed for optimal detection of damage from insects that have historically been the worst pests in the Region – defoliators in mixed-conifer, especially western spruce budworm, and bark beetles in all vegetation types. This timing does not work well for detecting damage from a few agents, especially spruce aphid and pathogen and insect defoliators of aspen. Chronic pathogens are usually not included in the aerial survey, except for defoliating foliar pathogens and unusual events. The piñon-juniper and low elevation dryland forest types are usually not surveyed. Acreage of piñon-juniper affected is usually only mapped when adjacent to the ponderosa pine type.

The Sky Island forests are particularly difficult to survey because the timing coincides with monsoonal storms. This is particularly true for the highest elevation forests. Additionally, it is my opinion that recent insect activity in the pine types has been underestimated for the Sky Island pine forests. I think that at such low latitudes, this damage is more visible earlier in the year, and therefore that it is difficult for the observer to distinguish between current year's damage and older damage.

The text portions of both the older and recent conditions reports often refer to activity that is not tabulated and for which no acreage is reported. These references are usually of a nominal nature (*e.g.*, "some roundheaded pine beetle activity adjacent to the road construction") or to non-timber-damaging activity (*e.g.* "in the campground"). This damage is not accounted in this report.

Regardless of any inherent problems in the data and reports, the conditions reports provide an excellent long-term record of insect activity that is quite useful. When looking at long-term records of biotic events, it is usually much more useful to know that damage increased from 25 ac to 12,000 ac than it is to know exactly which canyons or mountainsides were damaged, or to distinguish between 12,000 ac and 12,025 ac.

Some additional caveats and assumptions regarding interpreting aerial survey data and the conditions reports follow in a later section.

Results

Insect activity is here summarized by vegetation type: pines (Fig. 1), mixed-conifer (Fig. 2), spruce-fir (Fig. 3), and aspen (Fig. 4). Each of these types, except aspen, show distinct periods of increased insect damage during the 1950s and the last 20 years. As stated earlier, there would have been minor levels of insect activity in the intervening years, but if acreage was not reported it is not included in the data charts.

Acreage affected by insects in the pine vegetation type (Fig. 1; primarily ponderosa pine, but including Apache pine, Arizona pine, Chihuahua pine, Southwestern white pine, and piñon) was considerable during both the 1950s and contemporary periods, but was greater during the earlier period. In 1957, the year with the most damage reported, 36,580 ac were damaged by bark beetles, compared to 15,970 in 2000 (Fig. 1). Note that the data represents acreage damaged, not damage severity.

Bark beetle activity in pines has been very episodic on the Coronado N.F., with outbreaks associated with the 1950s and contemporary droughts. The 1950s outbreaks were attributed mostly to *Ips* sp. (mostly Arizona five-spined ips), and the contemporary outbreaks mostly to *Dendroctonus* sp. (roundheaded pine beetle, western pine beetle, Mexican pine beetle).

The 1950s damage to over 35,000 ac is an ecologically significant event for the isolated forests of the Coronado N.F., but the actual area is small compared to the 1.7 million ac damaged Region-wide in 1957 alone. The same is true for the contemporary outbreaks: almost 16,000 ac were damaged on the Coronado N.F. in 2000, but over 3 million ac were damaged Region-wide in 2003. Sheer size of the areas affected is not an adequate measure for the impacts to the ecosystem.

Southern pine beetle damage is distinguished from the other *Dendroctonus* bark beetles because the 2000 outbreak is the first recorded serious outbreak of that species in Arizona. This species is not recorded as a serious pest in Region 3 (Furniss and Carolin 1977), but it is known to attack Chihuahua pine and Apache pine. It is listed as one of several beetles that were active in 1973 – 1976 in

scattered areas in the Santa Catalina Mountains, killing a small amount of timber (125 mbf). But in 2000 a southern pine beetle outbreak caused severe levels of mortality on 11,260 ac of Chihuahua pine and Apache pine in 2000 in the Chirichahua Mountains.

Insect activity in the mixed-conifer vegetation type (Fig. 2) affected a larger area in the late 1950s than in recent years, but activity in recent years was from a greater variety of agents. Regarding the late 1950s Douglas-fir beetle outbreak that damaged over 13,000 ac, the 1957 report indicates that outbreak intensity was light, moderate, heavy, and very heavy on 6,820 ac, 3,680 ac, 480 ac, and 2160 ac, respectively. Nothing is noted in the text regarding the Coronado N.F., probably because outbreaks elsewhere in the Region were much larger, with damage in 1957 on 821,200 ac. The damage was probably ecologically significant for the Coronado N.F. ecosystems, but not catastrophic. Reports from that period were mostly concerned about timber volume loss, and therefore focused on the timber resources in northern Arizona and northern New Mexico. The reports do not indicate which mountain range(s) the damage occurred in. Douglas-fir beetle outbreaks are associated with extensive and severe crown damage, and with overstocking conditions of large trees. Drought may be an incidental factor in Douglas-fir beetle outbreaks. Factors that may have influenced the Douglas-fir beetle outbreak in the late 1950s were not described in the conditions reports.

Douglas-fir beetle activity has been elevated in recent years, but is still much less than what incurred in the late 1950s. However, the condition of much of the mixed-conifer is currently very susceptible to Douglas-fir beetle, and an outbreak is likely to be more intense than the one that occurred in the 1950s, causing serious damage.

Insect activity in the spruce-fir vegetation type (Fig. 3) was high in the late 1940s and early 1950s (Bennett 1953) and from 1992 to the present. In this case, the area damaged was similar for both periods, or perhaps greater for the contemporary period, even though the data shows 2000 ac of damage in 1952. The activity reported for 1952 (2000 ac) is a cumulative area for several years, not just 1952, and includes insect activity on Engelmann spruce and corkbark fir in both spruce-fir and mixed-conifer (Bennett 1953) (with the "mixed-conifer" probably including what is now called both mixed-conifer and transition zone). There is only about 700 ac of true spruce-fir, and about 4000 ac of mixed-conifer and transition zone in the Pinaleño Mountains. The contemporary outbreak acreages are reported for each year. In both cases most if not all of the spruce-fir zone was affected. However, the condition reports summarize acres affected, with no assessment of damage severity. Contemporary damage in the spruce-fir was considerably more severe than was damage during the 1950s. Fairly early (2001) in the spruce beetle and western balsam bark beetle outbreaks, 34 and 43% of the basal area of Engelmann spruce and corkbark fir, respectively, had been killed (Koprowski *et al.* 2005). Percent mortality (of density) approached

60% on some plots by 2002 (Lynch *in press*), and continued until the majority of the mature Engelmann spruce and corkbark fir was dead in the spruce-fir, and much of it was dead in the mixed-conifer. Obviously this did not happen in the 1950s, or there would not have been host trees to support the 1990s outbreak. Bennett (1953) indicated 2% stand mortality (density) in the spruce-fir for 1952, accounting for 18% of the stand volume (mortality was in large trees), and mortality of large trees during the 1990s outbreak was in excess of 90%.

What is remarkable about the contemporary activity in the spruce-fir vegetation type is the variety of insect species incurring outbreaks and the catastrophic nature of the damage. Historically, only spruce beetle and western balsam bark beetle incurred outbreaks in Southwestern spruce-fir. Recent insect outbreaks in the Pinaleño Mountain spruce-fir forest have included a geometrid defoliator (possibly *Nepytia janetea* Rindge[1]), spruce beetle, western balsam bark beetle, and spruce aphid. The severity of damage during the late 1940s and early 1950s was relatively light, killing about 18% of the spruce-fir over the affected acreage (Bennett 1953), while the recent outbreaks resulted in almost complete mortality to Engelmann spruce and corkbark fir over 6 or 8 in. dbh throughout the Pinaleño Mountain ecosystem, in both the spruce-fir and mixed-conifer vegetation types, and much of the smaller Engelmann spruce as well.

The recent insect outbreaks in spruce and fir in the Pinaleño Mountains started with an ice storm in the 1992-1993 winter. This damage was widely scattered in the high elevation forest, including the spruce-fir and some mixed-conifer. Spruce beetle and western balsam bark beetle populations began increasing in the damaged timber – population behavior that is typical for those species. Whether or not those populations would have increased to outbreak levels on their own will never be known for certain (probably yes, they would have), but beginning in 1996 a geometrid defoliator completely defoliated both Engelmann spruce and corkbark in the spruce-fir type, but not in the mixed-conifer (an outbreak of the same insect occurred in the White Mountains at the same time). The bark beetle populations that had been building up in the storm-damaged timber erupted in the geometrid-defoliated trees. Once spruce beetle populations reach high enough densities, outbreaks can become very aggressive, killing the overwhelming majority of suitable-sized host trees (6 in. dbh) until the host population is depleted (Furniss and Carolin 1977). Additionally, spruce aphid established in 1999 in the Pinaleño Mountains. This exotic damages Engelmann spruce of all size classes, killing 25-40% of severely damaged trees after a single defoliation episode (Lynch 2004). Outbreaks of all four insect species are associated with warm temperatures. Drought is not a primary factor in the

[1] The insect found in the Pinaleño Mountains and White Mountains of Arizona in the mid- to late-1990s was identified as *N. janetea*. Another insect in the Sacramento Mountains of New Mexico in the mid-2000s was also identified as *N. janetea*. Since the first species fed on Engelmann spruce and corkbark fir but not Douglas-fir, and the latter fed on Douglas-fir, white fir, and Southwestern white pine but not Engelmann spruce, it is unlikely that they are the same species. Probably they are closely related species, but which one is truly *N. janetea* is unknown.

population dynamics of the insects that recently had outbreaks in the spruce-fir, except possibly with spruce aphid.

No acreage has been mapped during the aerial detection surveys for spruce aphid, because the timing of the aerial survey is poor for detecting damage by that insect in southern Arizona. Virtually all of the Engelmann spruce has been defoliated by spruce aphid several times since 1999. Significant defoliation from spruce aphid was observed in 2000, 2001, and 2003 (feeding would have occurred the previous fall and winter) (Lynch *in press*).

Aspen has been damaged by a variety of insect and pathogen defoliator in recent years. It appears that this damage is unprecedented, which is consistent with the West-wide decline of aspen in recent years.

Associations with Climate

Insect activity for each vegetation type was charted against Palmer Drought Severity Index (PDSI) instrumental records for Region 3 from the National Climate Data Center (NCDC 2006) (Fig. 5).

Bark beetle activity was high during both the 1950s and contemporary drought periods (Fig. 1). The 1950s outbreak damaged over 35,000 ac. Though an ecologically significant event for the Coronado N.F., it was minor compared to the 1.7 million ac damaged Region-wide in 1957 alone. The 1950s outbreak is attributed mostly to *Ips* sp. (mostly Arizona five-spined ips), and the 1990s outbreak mostly to *Dendroctonus* sp. (western pine beetle, roundheaded pine beetle, and Mexican pine beetle). A smaller outbreak of roundheaded pine beetle in ponderosa pine and Southwestern white pine in the early 1990s does not appear to be drought related, but the pockets of beetle activity began developing in 1988 and 1989, which were dry. Later damage in the late 1990s and early 2000s is drought-associated bark beetle activity, and coincides with the regional trend at that time.

Insect activity in the mixed-conifer type does not appear to be either clearly associated with or independent of drought. Douglas-fir beetle outbreaks are associated with severe crown damage to Douglas-fir from fire or defoliation (usually severe crown damage over extensive areas) and high stand stocking in large mature trees, and possibly weather conditions (drought and temperature conditions). Drought alone is not known to initiate an outbreak, so the late 1950s event may have been associated with a fire, which was in turn associated with drought. The timing of the Douglas-fir beetle outbreak during the 1950s was later than the timing of the drought-associated outbreaks of bark beetles in pine. However, Douglas-fir beetle activity on the Coronado N.F. coincided with a similar Region-wide trend, so a climatic factor probably is involved. Outbreaks of fir engraver are known to be associated with most stress agents, including drought, fire scorch, defoliation, and windthrow.

The various insect species that incurred recent outbreaks in the Pinaleño spruce-fir ecosystem have outbreak dynamics that are known to be associated with periods of warm temperature.

Due to the episodic nature of insect outbreaks, damage must be evaluated over an extended period before designating any shorter period as "unusual". Certainly insect activity in Coronado N.F. forests has increased in the last decade or so. However, the acreage affected is not greater than what was damaged during the 1950s drought. The severity of the damage may be greater, and may have been influenced by several factors, but that is difficult to tell from the historic documents. Two things appear to be different about the current insect activity compared to the historic record. First is that the species of bark beetles causing damage is different. The recent outbreaks in the pine vegetation type have been mostly from *Dendroctonus* species, which have aggressive population dynamics known to be associated with drought and overstocking, and sometimes warm temperatures. They primarily attack larger trees. The 1950s outbreaks were mostly attributed to *Ips* species, especially Arizona five-spined ips. This species has historically been the most destructive pine bark beetle in central and southern Arizona, and primarily attacks saplings and pole-sized trees, frequently on marginal sites and in recently disturbed areas. This change in ecosystem processes could be caused by changes in forest structure (greatly increased density and stocking) and/or to warmer climate trends.

Certainly the severity of the damage, and variety of outbreaking species, has been unusual in the Pinaleño spruce-fir forest in the last 10 years (Koprowski *et al.* 2005, Lynch *in press*). If similar damage has occurred before in the Pinaleño spruce-fir forest, it happened at least 300 years ago. Outbreaks of spruce beetle, western balsam bark beetle, the geometrid defoliator, and spruce aphid are associated with periods of warm climate. Spruce aphid is exotic, and not enough is known about this species' ecology in montane ecosystems to predict it's future impact with certainty, though what is know so far indicates that it will continue to be a serious problem (Lynch 2004). The spruce-fir forest, faced with unprecedented conditions, faces an uncertain future.

Conclusions

Given the inherent uncertainties in the data, recent changes in insect population behavior are cause for concern, but not alarm. The area affected by insect outbreaks in recent years is similar to or smaller than the area affected during the 1950s outbreak. The severity of recent damage in the pine and mixed-conifer vegetation types is probably similar to what occurred in the 1950s. However, damage in the spruce-fir is considerably more severe. The species of insects incurring outbreaks in pine and spruce-fir are dissimilar when contrasting the two periods, with recent outbreaks being of species with the potential for more aggressive population dynamics. Also, a greater number of species have

incurred outbreaks in the contemporary period. The changes in the species that have been incurring outbreaks may be related to several factors: the overgrown nature of the contemporary forest, changes in temperature regimes (especially coincidental with the contemporary forest condition and drought), and the introduction of an exotic. There is the possibility that the 1950s survey efforts were not sufficient to determine which species were incurring outbreaks, but this is not likely.

It would not be prudent to expect the next 10 or 20 years to be similar to the 1970s and 1980s with regards to insect activity. Contemporary trends have enough differences from historic trends to anticipate altered ecosystem processes. The coincidental occurrence of competitive vegetation densities, drought, and warm climate has increased forest vulnerability to herbivorous insects, especially bark beetles. There is potential for catastrophic insect outbreaks in the pine and mixed-conifer forests, but it is difficult to characterize the risks in a temporal framework. There is more uncertainty regarding future insect outbreaks than the past record indicates.

Even in the face of uncertainty regarding future climate and insect activity, general management recommendations for reducing susceptibility and vulnerability to insect outbreaks remain the same: Improve tree vigor and maintain forest health by maintaining natural species, size, and age class distributions.

Assumptions and Caveats about the Data

There are some relatively long periods in the record without reported insect activity. This should not be taken to mean that there was no insect activity, but rather that activity was minor. Affected acreage reported here was considered to be zero for years where conditions were described as "normal" or insect populations were said to be "at endemic levels". Additionally, there are reports of activity in the text in many instances of minor infestations that are not included here.

The aerial detection surveys, from which the conditions reports are compiled, map activity each year. Some of the same acres may be mapped in consecutive years for the same damage agent, usually indicating that the insect outbreak attacks more trees on the same sites in subsequent years, as well as the outbreak expanding to additional areas. A GIS-based analysis would account for some of this overlap, but maps are not available for the entire record.

Only activity from the major damaging insect species (Table 1) is summarized here. No pathogens, other than as part of aspen or true fir complexes, are reported.

When summarizing historic reports, it is often necessary to make some judgment calls regarding the reported data. Though the data for the Coronado N.F. is pretty consistent, some inconsistencies do occur. I made the following assumptions and decisions regarding the data in the conditions reports:

True fir beetle and fir engraver activity occurred in the mixed-conifer unless they were specifically reported as in the spruce-fir. In the Southwest, these insects mostly occur on white fir and Douglas-fir. However, they also attack corkbark fir, and the conditions reports sometimes indicated damage to corkbark fir. Corkbark fir occurs in both the spruce-fir and mixed-conifer vegetation types, and I assumed that bark beetles attacking corkbark fir occurred in the mixed-conifer, unless western balsam bark beetle and/or the spruce-fir type was specified, in which case I assumed that the activity occurred in the spruce-fir vegetation type. Most of the reports for either true fir beetle or fir engraver specifically mention attacks on white fir and Douglas-fir. This assumption is probably wrong in some instances.

Fifteen acres of western spruce budworm damage reported in 1992 in the Chiricahua Mountains is an error made by a new, inexperienced surveyor. This insect is not reported from southern Arizona, and on reflection after many years of service, the surveyor believes that he mapped an abundant cone crop, a common error with inexperienced observers. Certainly a single year of damage from either western spruce budworm or Douglas-fir tussock moth would be very unusual, as both of these defoliators have multiple-year outbreaks.

In my opinion, the detection surveys under-represent recent insect activity in the high elevation forests on the Coronado N.F., especially in the Pinaleño Mountains. The recent acreage reported for spruce beetle and western balsam bark beetle are only for damage in the spruce-fir type, and not for damage in the mixed-conifer type and the transition zone. The outbreaks of these bark beetle species devastated the spruce-fir type, and then killed the majority of the large Engelmann spruce and corkbark trees in the lower vegetation zones as well, but only the completely devastated spruce-fir was mapped. Defoliation and mortality by spruce aphid is not mapped at all, due to the timing of the aerial survey flights, when the tops of the Sky Island Mountains are obscured by monsoon storms and when aphid damage is not easy to detect. In contrast, it should be noted that the area reported in 1952 as damaged by spruce beetle and western balsam bark beetle included the area in the Pinaleño Mountains above 8,500 ft, which would include all of the spruce-fir type plus some of the mixed-conifer type and transition stands. The 1952 report was based on both aerial survey and ground survey data (Bennett 1953). Additionally, I think that a survey conducted earlier in the season might detect additional pine bark beetle activity. The timing of pine tree crown fading should be investigated to determine if the historic time frame is best for insect detection surveys in southern Arizona.

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Fig. 1. Acreage of ponderosa pine, Apache pine, Chihuahua pine, and piñon affected by Ips bark beetles (green), Dendroctonus bark beetles (brown), southern pine beetle (blue), and drought (red), 1940-2005 Note that data for 1949, 1950, 1959-1963, 1965-1970, and 1981 are missing (opaque gray).

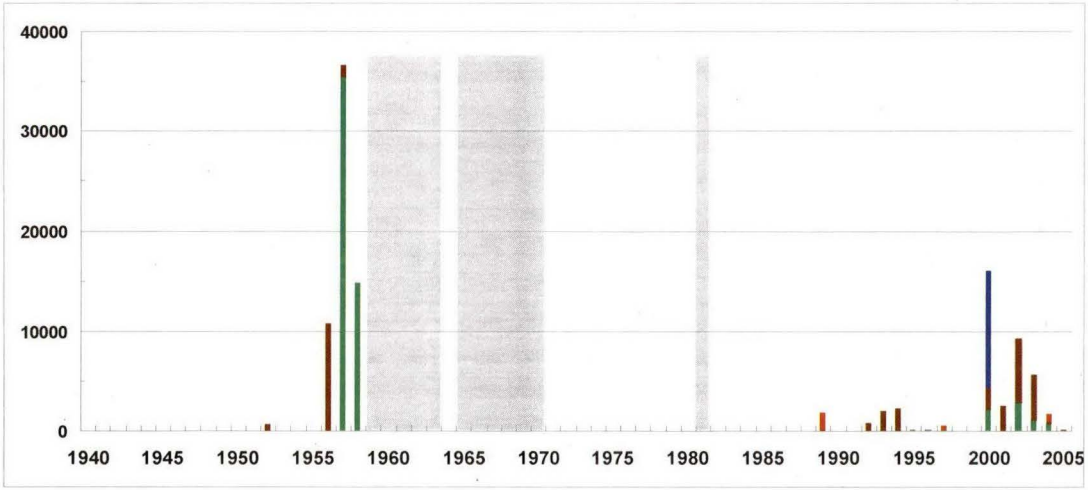

Fig. 2. Acreage of mixed-conifer affected by an ice storm (yellow), drought (red), bark beetles (brown, primarily Douglas-fir beetle and fir engraver) and true fir complex (bright green) 1940-2005. Note that data for 1949, 1950, 1959-1963, 1965-1970, and 1981 are missing (opaque gray).

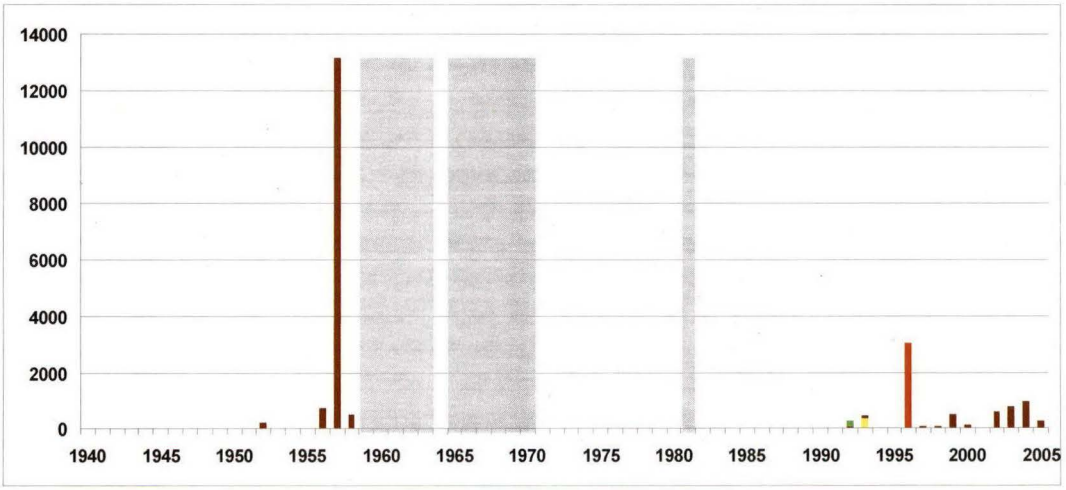

Fig. 3. Acreage of spruce-fir affected by an ice storm (yellow), spruce beetle and western balsam bark beetle combined (green; 1952 includes acreage in the mixed-conifer as well), a geometrid defoliator (possibly Nepytia janetae (magenta)), and true fir beetles (brown), 1940-2005. Years with spruce aphid activity (from Lynch (*in press*) are indicated by "S". Note that data for 1949, 1950, 1959-1963, 1965-1970, and 1981 are missing (opaque gray).

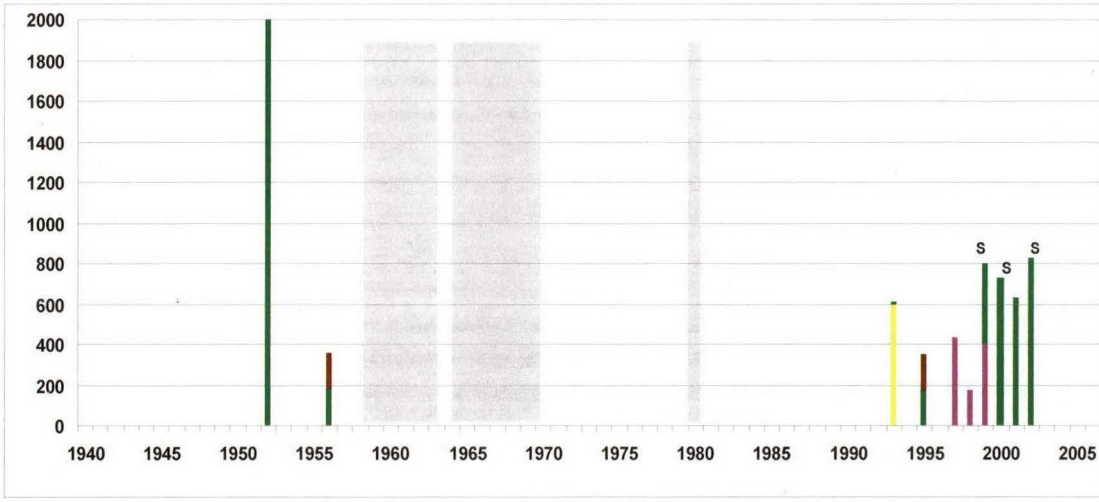

Fig. 4. Acreage of aspen defoliated by insects and disease (black) and affected by weather in addition to defoliation (red), 1940-2005. Note that data for 1949, 1950, 1959-1963, 1965-1970, and 1981 are missing (opaque gray).

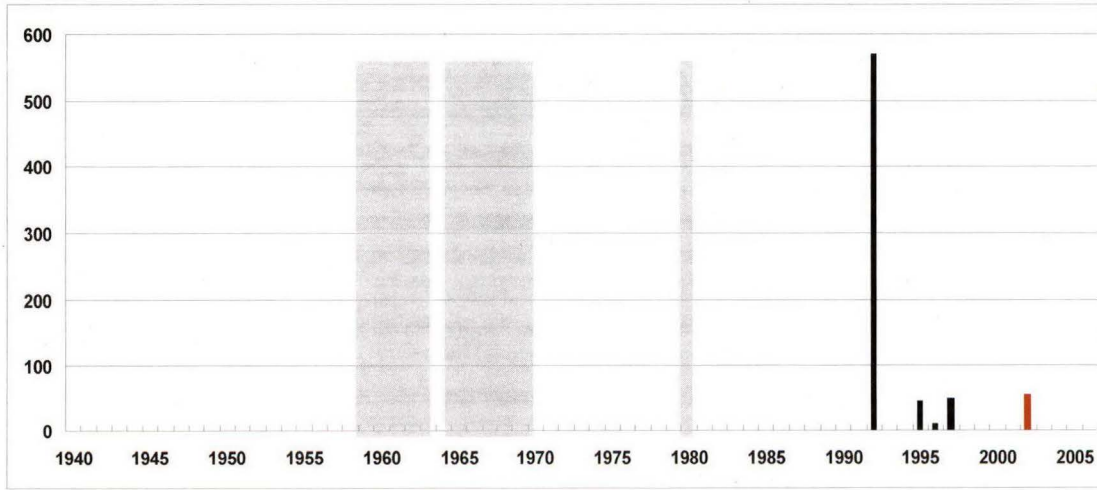

Fig. 5. Acreage (left axis) of pine (green bars), mixed-conifer (brown bars), spruce-fir (blue bars) and aspen (yellow bars) affected by insect outbreaks and foliar pathogens, and instrumental PDSI values (right axis) for Region 3 (violet line), 1940-2005. The dashed violet line demarcates the zero PDSI value. Note that insect data for 1949, 1950, 1959-1963, 1965-1970, and 1981 are missing (opaque gray).

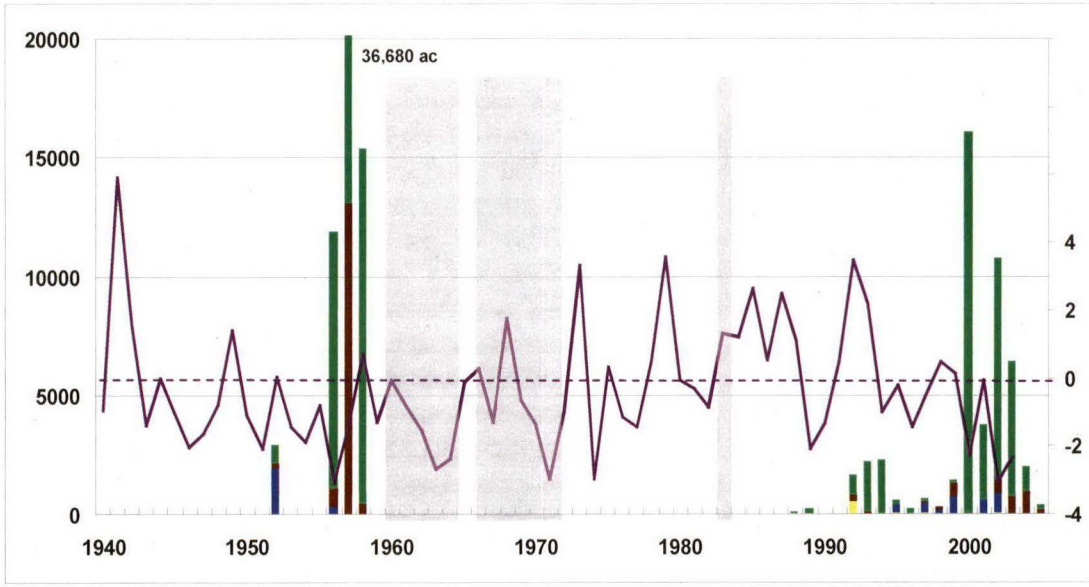

Table 1. Common and scientific names of insects and pathogens referred to in this report.

INSECTS		PATHOGENS
Arizona five-spined ips	*Ips lecontei*	Marssonina leaf blight
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Armillaria root disease
Douglas-fir tussock moth	*Orgyia pseudotsugata*	black leaf spot
fir engraver	*Scolytus ventralis*	sooty bark canker (on aspen)
Geometrid defoliator	Possibly *Nepytia janetae*	black canker
large aspen tortrix	*Choristoneura conflictana*	cryptosphaeria canker
Mexican pine beetle	*Dendroctonus mexicanus*	cytospora canker
mountain pine beetle	*Dendroctonus ponderosae*	
roundheaded pine beetle	*Dendroctonus adjunctus*	
southern pine beelte	*Dendroctonus frontalis*	
spruce aphid	*Elatobium abietinum*	
spruce beetle	*Dendroctonus rufipennis*	
true fir beetles	bark beetles attacking white fir and corkbark fir, usually fir engraver and/or western balsam bark beetle	
western balsam bark beetle	*Dryocoetes confusus*	
western pine beetle	*Dendroctonus brevicomis*	
western spruce budworm	*Choristoneura occidentalis*	
western tent caterpillar	*Malacosoma californicum*	